NASA TECHNICAL TRANSLATION NASA TT F-11,564

NASA TT F-11,564

USE OF ELECTRONIC COMPUTERS FOR DETERMINATION OF THE AERODYNAMIC CHARACTERISTICS OF AIRCRAFT

Professor O. M. Belotserkovskiy

Translation of "Ispol'zovaniye Elektronno-Schetnykh Mashin Dlya Opredeleniya Aerodinamicheskikh Kharakteristik Letatel'nykh Apparatov".
Paper presented at the Eighteenth Congress of the International Astronautical Federation, Belgrade, 25-30 September, 1967, 7 p.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 FEBRUARY 1968

USE OF ELECTRONIC COMPUTERS FOR DETERMINATION OF THE AERODYNAMIC CHARACTERISTICS OF AIRCRAFT

Professor O. M. Belotserkovskiy

ABSTRACT. If a problem is formulated correctly mathematically and a numerical algorithm for its solution by electronic computer can be developed, considerably more and considerably less expensive information can be produced than by experimental methods. The flow about a blunt aerodynamic form with a break in the generatrix is analyzed as an example of this. Cones are analyzed with various half aperture angles (5, 0 and 10°) and with an oncoming stream moving at Mach 4. The intensity of the "hanging" compression discontinuity first increases sharply, then gradually decreases with increasing distance from the blunt nose.

Investigations of cosmic space, particularly manned space flights, are of great interest from the point of view of the development of surface aerodynamics. /1[1]

The widespread cosmic investigations which have been performed have set an entire range of completely new problems before engineers and aerodynamic scientists, which has required the development of methods and approaches for their solution which are new in principle. Among this group of new problems we can include investigations in the transsonic and hypersonic range, viscous fluid flow, etc. We should note that with these problems we must keep in mind the various physical and chemical transformations of the gas and analyze the most varied forms of aircraft. In particular, future passenger flights will of course require the development of economical landing stages with aerodynamic braking. Blunt aerodynamic forms will be widely used. This places the problem of determination of the optimal aerodynamic forms, heat regimes and various flow characteristics necessary for engineering application before today's investigators.

The past fifteen years has been a stage of intensive development of various scientific and engineering methods of investigation, in which a decisive role in theoretical developments has been played by the broad application of electronic computers to applied investigations. This has allowed the performance of rather complete studies of complex, nonlinear gas dynamics problems.

---

[1] Numbers in the margin indicate pagination in the foreign text.

If a problem is correctly formulated mathematically and if a numerical algorithm for its solution by electronic computer can be developed, the result of the calculation is the production of considerably more and considerably less expense information than can be produced experimentally (I do not intend to deprecate the value of experiment, which always remains the basis of physical investigation). In turn, the results of many calculations, analytical investigations and experiments allow us to refine the information produced into definite regularities and theorems. Please allow me at this time to expound some new results produced by numerical solution of certain aerodynamics problems which were reported at the recent Conference on the Mechanics of Fluids and Gasses in Poland [1]. /2

As we know, recently great practical interest has been shown in the study of the characteristics of supersonic flow about blunt bodies with a break in the generatrix. The study of such phenomena is essentially complicated first of all by the presence of an area of mixed flow before the nose portion of the body, as well as the presence of singularities at the point of the break in the formation of secondary shock waves. Numerical methods have been used to solve this important problem completely and to produce widely varied flow characteristics.

As an example, let us analyze the flow about blunt aerodynamic forms with a break in the generatrix.

Figures 1 and 2 show the shock waves and "hanging" discontinuities in compression (dotted lines) which arise in the supersonic zone with flow about cones with spherical blunt tips and a sonic break ($\chi = 30°$; adiabatic index $x = 1.4$). Cones are analyzed with various half aperture angles ($\omega = 5°$, $0°$, $10°$) and Mach number of the oncoming stream $M_\infty = 4$. /3

The intensity of the "hanging" compression discontinuity first increases sharply, then, with increasing distance from the blunt nose, gradually decreases. In the cases in question, the maximum rotation angle of the stream upon passage through the "hanging" discontinuity reaches several degrees, while at a distance of 30-40° the blunting of this angle was only a few seconds. The position of the "hanging" compression discontinuities was determined numerically for the first time [2]. It is interesting to note that in the cases analyzed, where there was a "hanging" compression discontinuity, the form and position of the head shock waves (in the area preceding their intersection with the "hanging" discontinuity) correspond (with identical Mach numbers of the oncoming stream) for various half aperture angles of the cone at least within the range of change $-10° < \omega < 10°$. The appearance of the "hanging" compression discontinuity is explained by overexpansion of the stream as the flow rotates about the angular point and subsequent compression and retarding of the stream on the lateral surface of the body.

Figures 3 and 4 show the change in the boundaries of the rotation zone of the stream with various adiabatic indices x and various half aperture angles of the spherical segment χ. Here also we see the characteristics limiting the area of the influence of blunting and of the break. On Figure 4 where M_∞ = 4 (solid line) and M_∞ = 6 (dotted line) we show the distribution of pressures along the lateral surface of the cylinder with spherical blunting and various half aperture angles of the segment (the first two cases are for sonic break, the third case for a supersonic break). Figure 6 illustrates the change of the departure value of the shock wave from the body ϵ_0 along the axis of symmetry with various positions of the break on the sphere, while Figure 7 shows the dependence of the wave drag coefficient C_x of the spherical segments on the Mach number. /4

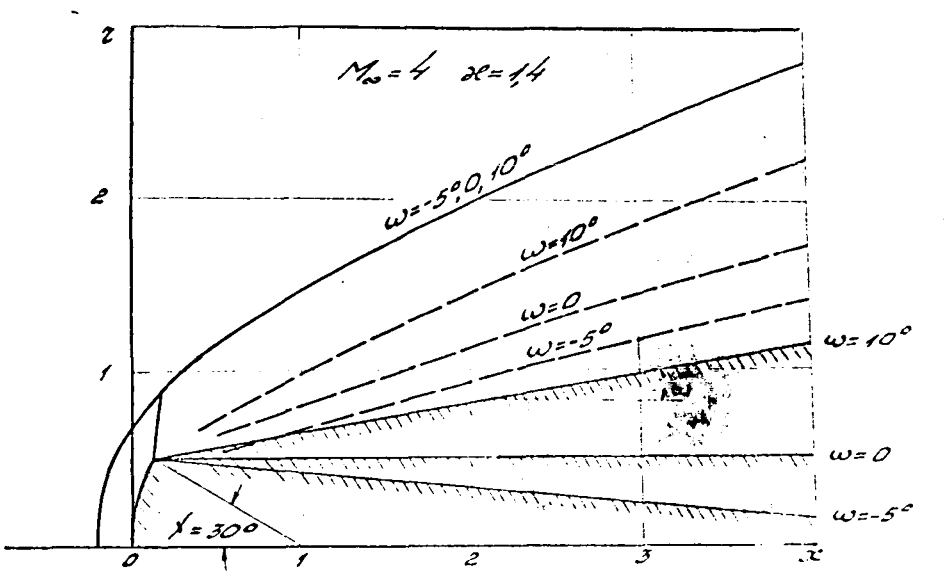

Figure 1

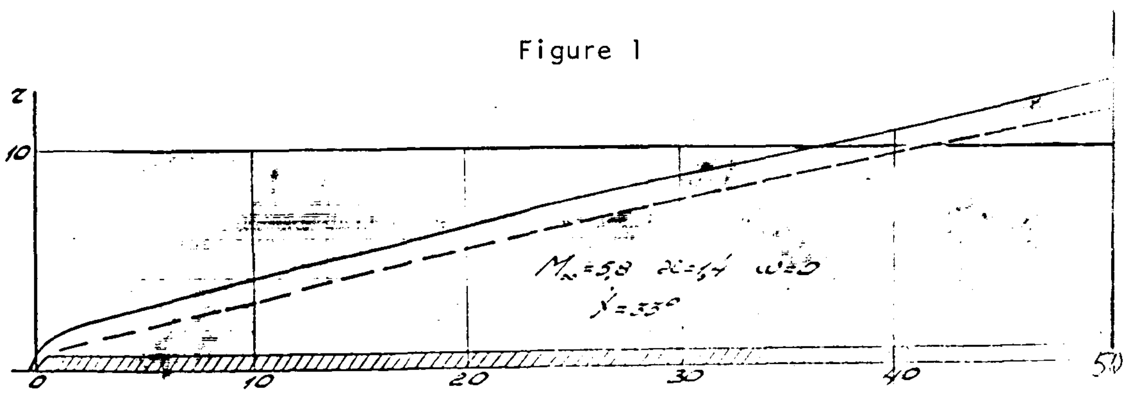

Figure 2

A detailed experimental investigation of flow beyond the departed shock wave was conducted by G. M. Ryabinkov. In [2], a detailed description of the experimental techniques and methodology is presented, as well as the results of the investigation in the form of tables and graphs. Figure 8 shows a comparison of the experimental data of G. M. Ryabinkov,

V. G. Maslennikov (for ϵ_0) and the results of calculation by the integral relations method for a sphere and rotation ellipsoids. The results presented include the distribution of pressure along the body, as well as the form and position of the head shock waves. We see that the correspondence of theoretical and experimental data is quite good in all cases.

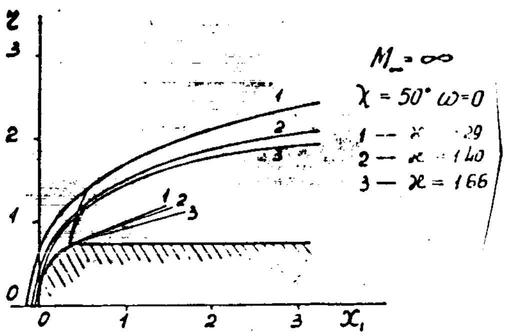

Figure 3

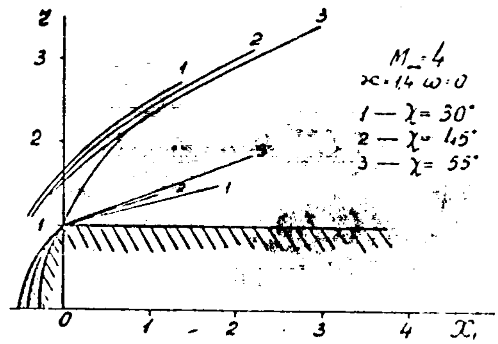

Figure 4

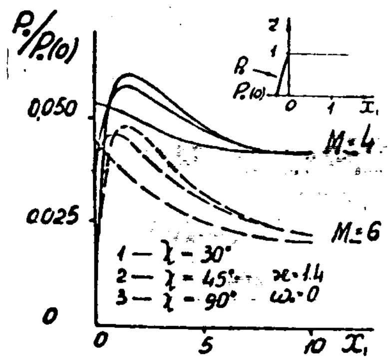

Figure 5

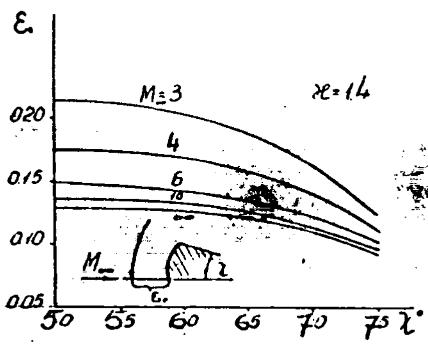

Figure 6

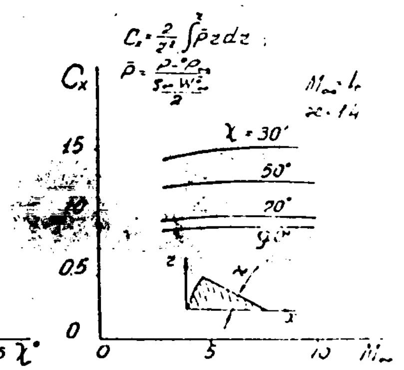

Figure 7

At the present time, broad theoretical investigation of the spatial and viscous problems of gas dynamics is going on; flows with dissociation, radiation, absorption, etc. are being studied [2].

Only the interweaving and development of various types and methods of investigations will allow us to produce the necessary information concerning the essence of the phenomena and to solve the great problems involved in manned space flights.

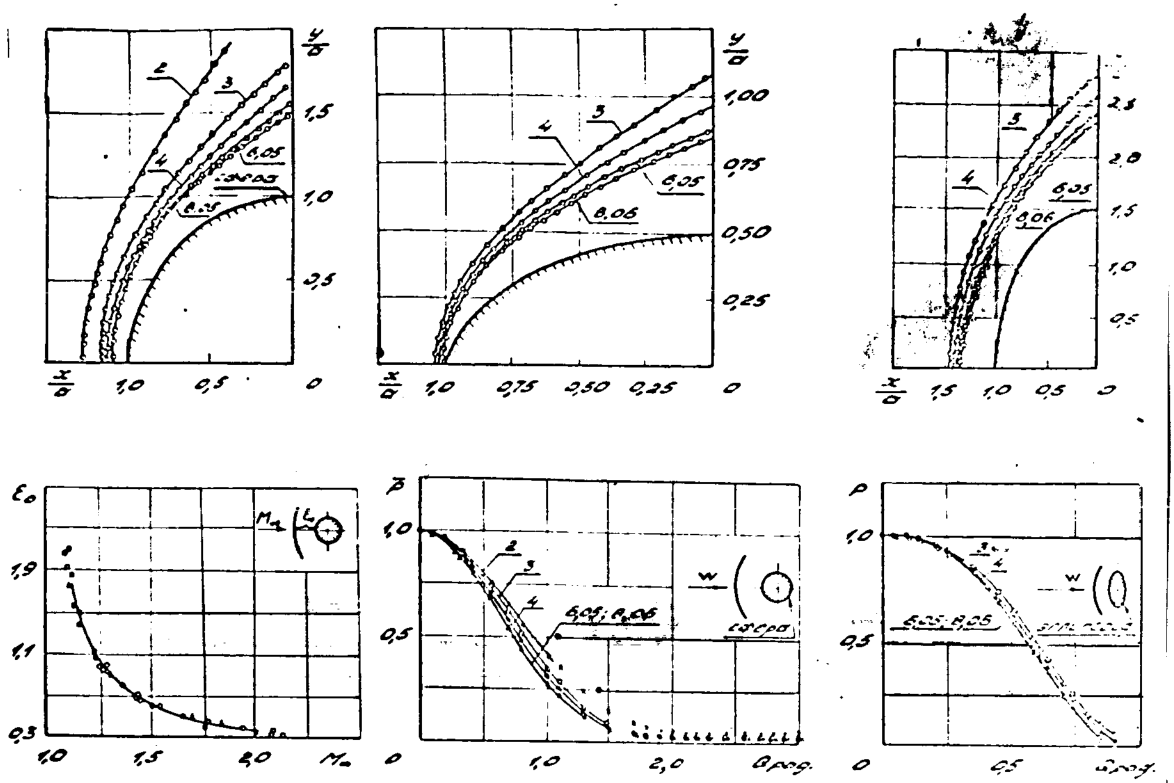

Figure 8

REFERENCES

1. Belotserkovskiy, O. M., Shifrin, E. G., "Investigation of Certain Transsonic Gas Flows," report at the Conference on the Mechanics of Fluids and Gases, Poland, Tarda, 18-23 September 1967.
2. Belotserkovskiy, O. M. (editor), *Obtekaniye Zatuplennykh Tel Sverkhzvukovym Potokom Gaza (Teoreticheskiye i Eksperimental'nyye Issledovaniya)* [Supersonic Gas Flow About Blunt Bodies (Theoretical and Experimental Investigations)], a collection of works, Academy of Sciences USSR Computer Center Press, Moscow, First Edition, 1966, 338; Second Edition 1967, 450.

Translated for the National Aeronautics and Space Administration under contract No. NASw-1695 by Techtran Corporation, P.O. Box 729, Glen Burnie, Maryland 21061